INTERACTIONS OF SMALL-SCALE PHYSICAL MIXING PROCESSES WITH THE STRUCTURAL MORPHOLOGY AND BLOOM DYNAMICS OF NON-SPHEROID DIATOMS

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LONG TERM GOALS

Our long term goal is to understand the ecology of the large, colonial diatoms which frequently dominate the phytoplankton of coastal shelves, upwelling areas, fjords and banks. We are interested in ways in which colony size and shape interact with small scale physical mixing processes and optics to regulate the distribution of diatoms. We wish to understand these processes in sufficient detail to be able to predict bloom dynamics, size structure and the optical properties of the ocean.

OBJECTIVES

Our current research addresses the role of shear in regulating diatom blooms. We wish to understand how small-scale physical mixing processes affect diatom growth, mortality and the size spectrum of colonies in the ocean. First order questions include (1) What is the relative susceptibility of different diatoms to shear stress? (2) Does a colony's past history affect its susceptibility to breakage? (3) Can diatom mortality be predicted based on larger scale physical forcing factors such as wind speed? (4) Do highly stratified regions of the water column provide sufficient refuge from disruption to lead to the formation of phytoplankton layers? This work is supported by ONR Biological Oceanography.

APPROACH

Laboratory experiments are conducted to test the hypothesis that shear can break diatom colonies, that sensitivity to disruption varies between species, and that it is dependent on the silicate concentration of the water the diatoms were grown in. They are carried out on clonal cultures of diatoms isolated from East Sound, which are grown in 20L polycarbonate tanks. Uniform illumination (200µM photons·m^{-2}·sec^{-1}) is provided from

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the side by cool white fluorescent lamps. Cultures are initially grown under quiescent conditions, and then exposed to shear resulting from dissipation of von Kármán eddies shed by a towed, cylindrical rod. Five different motors provide a range of towing speeds, and thus a range of turbulent dissipation rates. A sixth unstirred tank serves as a control. There is no turbulent energy input to this tank, and no detectable convective movement. Effects of exposure to shear are quantified in two ways. First, colonies are videotaped directly in the tanks. From these low-magnification images, particle length is digitized using the program NIH Image (U.S. National Institutes of Health), run on a PowerMac 9500MP. For estimates of cell rupture and mortality, tanks are gently subsampled, and material examined under the microscope. Turbulent velocity fluctuations in the tanks have been measured with a SonTek ADV (SonTek Corp., San Diego, CA), and the turbulent dissipation rate (ε) calculated by the dimensional approximation: u'^3/L. The calculated ε tank values for the motors range from 8×10^{-5} to 5×10^{-8} watts/kg.

In the field, Donaghay's high resolution profiling system is used to locate optical layers by means of their particulate absorption signature. Siphon samples are collected from inside and outside of layers. Both whole water and concentrated samples are preserved for later enumeration of >20µm phytoplankton cells. A subsample from each depth is microscopically examined within 15 minutes of collection, and images of the planktonic community are recorded on videotape. Cultures of representative diatoms are isolated from East Sound and returned to Rhode Island for experimental work.

WORK COMPLETED

In 1997, approximately 40 new clonal cultures of diatoms were established to add to our 1996 collections. Taxa were selected which are common at our field site, and which represent a variety of sizes, shapes and modes of colony formation (e.g. stiff vs. flexible). This large collection provides us with flexibility regarding choice and condition of taxa used in the experiments.

We have conducted two series of replicated experiments. The first used *Chaetoceros vanheurckii*, a common and sometimes abundant diatom along the west coast of North America. This experimental design employed two levels of turbulence ($\varepsilon = 8 \times 10^{-5}$ and 5×10^{-8} watts/kg) and two levels of silicate (~10µM and ~100µM), since it has been suggested that the strength of the frustules is related to the silicate concentration of the water cells were grown in (Paasche 1980). The second set of replicated experiments have been carried out on *Chaetoceros vanheurckii*, *Chaetoceros concavicornis, Pseudonitzschia fraudulenta* and *Odontella longicruris*. All tanks were enriched to a single (~10µm) level of silicate, and colonies were exposed to all five levels of turbulent dissipation rate.

During the 1997 field season, a fine scale profile of siphon samples from the upper 15 meters of the water column in East Sound was collected in conjunction with Donaghay's & Gifford's programs. Phytoplankton cells in the >20µm fraction were enumerated by J. Sullivan under Donaghay's grant, and we have compared them with the fine scale optical and physical structure.

RESULTS

When grown in tanks under quiescent conditions, the diatoms formed long chains which were evenly spaced throughout the tanks. Colonies of *Chaetoceros concavicornis* were only about 1mm in length, but those of *Pseudonitzschia fraudulenta* were as much as 14mm long. Colonies of *Chaetoceros vanheurckii*, *Pseudonitzschia fraudulenta* and *Odontella sinensis* all broke into shorter pieces when exposed to turbulence. *Chaetoceros concavicornis* showed little breakage. The most striking results were found in *Chaetoceros vanheurckii*. In this taxon, adjacent cells in a colony are fused together and can not simply separate. When exposed to a turbulence level of 8×10^{-5} watts/kg for 15 hours, 93% (± 5% SD) of the colonies broke, resulting in the rupture and death of some cells in the chain. Laboratory experiments support the hypothesis that shear resulting from small-scale turbulence can break diatom colonies. The resulting size frequency spectrum is dependent upon the turbulent energy dissipation rate colonies were exposed to, and is species-specific. Mortality of cells is dependent on the particular species of diatom, and the silicate concentration of the water cells were grown in.

Examination of quantitative and qualitative siphon samples collected on sub-meter scale profiles, and samples taken inside and outside of layers in East Sound have demonstrated that chlorophyll peaks may represent several kinds of net-phytoplankton communities. A peak may reflect an increase in cell number of a single, dominant taxon, or an increased concentration of an otherwise homogeneously distributed flora. Alternatively, a peak (or peaks) may be composed of thin layers dominated by different organisms. Comparison of fine scale phytoplankton distributions to fine scale optical distributions suggests that layers dominated by particular kinds of phytoplankton may have different optical properties. Examination of video records demonstrate that some taxa (e.g. *Chaetoceros vanheurckii*, *Eucampia zodiacus*, *Odontella sinensis*) are frequently broken or damaged in near surface (< 2m) samples, but may form extremely long colonies elsewhere in the water column.

IMPACT

Observations made in East Sound in May 1995 suggested that wind forcing from a sudden storm created enough shear in the water column to mechanically break large colonial diatoms. Concomitantly, this event changed the vertical distribution of phytoplankton, reduced its biomass, increased the spectral absorption of light by dissolved organic material and altered the species composition of the phytoplankton community.

Laboratory experiments have demonstrated that small-scale turbulence can change the particle size frequency spectrum, and can rupture cells of some species, releasing their organic contents into the water column. The results clearly support the hypothesis that wind events can result in mechanical breakage of large colonial diatoms and the resulting change in the optical properties of the water column. Since the response is species specific, it suggests that turbulence may affect the species (and size and shape) composition and succession of the diatom flora. Turbulence resulting from wind-forcing may contribute to thin-layer formation by destroying colonial diatoms in the surface layer.

RELATED PROJECTS

This project is closely connected to Donaghay's ongoing ONR-sponsored investigations of fine scale physical structure and patch dynamics. There are numerous areas for close collaboration with other investigators in the ONR Thin Layers field program. Accurate data on phytoplankton species composition and distribution is critical to Holliday's & Donaghay's question regarding the co-occurrence of phyto- and zooplankton layers. It will be used as a biological tracer to test Donaghay's shear-dispersion model of patch formation. Information on the taxonomic composition of layers and aggregates will be available to Alldredge, Gifford, and may also be useful to Zaneveld and Perry . Additionally, I am Co-PI (with P. Hargraves, URI) on an NSF/Biotic Systems & Inventories grant. This project will result in a book which is a field guide to the marine planktonic diatoms of the northeast US coast, a total of about 225 taxa. This information is relevant to the diatoms of the west coast, and will be useful to researchers working in the temperate areas of both oceans.

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